



Recommendation ITU-R F.2011
(01/2012)

**Evaluation of interference from
high-altitude platform (HAPS) gateway
links (HAPS-to-ground direction) in the
fixed service to conventional fixed wireless
systems in the range 5 850-7 075 MHz**

F Series
Fixed service

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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R F.2011*

Evaluation of interference from high-altitude platform (HAPS) gateway links (HAPS-to-ground direction) in the fixed service to conventional fixed wireless systems in the range 5 850-7 075 MHz

(2012)

Scope

This Recommendation provides a method for the evaluation of interference between fixed service (FS) systems using high-altitude platform stations (HAPS) gateway links (HAPS-to-ground) and conventional fixed wireless systems in the range 5 850-7 075 MHz in response to the technical study invited by Resolution 734 (Rev.WRC-07). The method is used to determine areas where specific values of I/N would be exceeded in an FS receiver. Results include plots and calculations of the areas for various specified I/N values.

The ITU Radiocommunication Assembly,

considering

- a) that new technology utilizing high-altitude platform stations (HAPS) in the stratosphere has been developed to provide high-capacity services;
- b) that some administrations intend to operate the systems using HAPS in the bands allocated for such use by the Table of Frequency Allocations or by footnotes for the fixed service;
- c) that in addition to such service links, there is a requirement for gateway links which can connect the service links to the public switched telephone network (PSTN), broadband data networks, cellular telephone systems and sound and television broadcasting providers;
- d) that WRC-07 adopted Resolution 734 (Rev.WRC-07) requesting ITU-R sharing studies with a view to identifying two channels of 80 MHz each for gateway links for HAPS in the range from 5 850 to 7 075 MHz, in bands already allocated to the fixed service, while ensuring the protection of existing services;
- e) that large portions of this band are heavily used by existing services,

recommends

that, in response to the technical study stated in *considering d)*, to evaluate interference from HAPS gateway links (HAPS-to-ground) in the fixed service to conventional fixed wireless systems in the range 5 850-7 075 MHz the methodology described in Annex 1 should be used.

* This Recommendation has been prepared in support of World Radiocommunication Conference 2012 (WRC-12) Agenda item 1.20. In the event that WRC-12 does not identify spectrum for gateway links for high-altitude platform stations in this band, the Recommendation will be suppressed.

Annex 1

Evaluation of interference from high-altitude platform gateway links (HAPS-to-ground direction) in the fixed service to conventional fixed wireless systems in the range 5 850-7 075 MHz

1 Introduction

This Annex presents a methodology for determining the ratio of interference power to noise power at the input of a point-to-point receiver in the fixed service due to operation of HAPS gateway downlinks. This is one of the interference cases that should be considered under WRC-12 Agenda item 1.20. The parameters and models used in the analysis are described in Section 2; the possible I/N criteria that might be applied are described in Section 3; the methodology is described, applied and the results obtained with it are presented in Section 4 for the case where the HAPS platform is transmitting to only one gateway station. In Section 5, consideration is given to the aggregate interference when the HAPS platform is transmitting to multiple gateway ground stations in a symmetrical configuration. In Section 6, considerations are given to the effect of other parameters on the results obtained. The focus of the studies in this document is on the band 5 925-6 875 MHz, because this band is heavily used by the FS.

2 System description and parameters

The HAPS system under consideration in this study provides communication to five gateway stations. Figure 1, which is taken from Recommendation ITU-R F.1891, shows the geometric configuration of the system. The characteristics of the signals transmitted by the HAPS platform transmitter are the ones given in Recommendation ITU-R F.1891. They are summarized in Table 1.

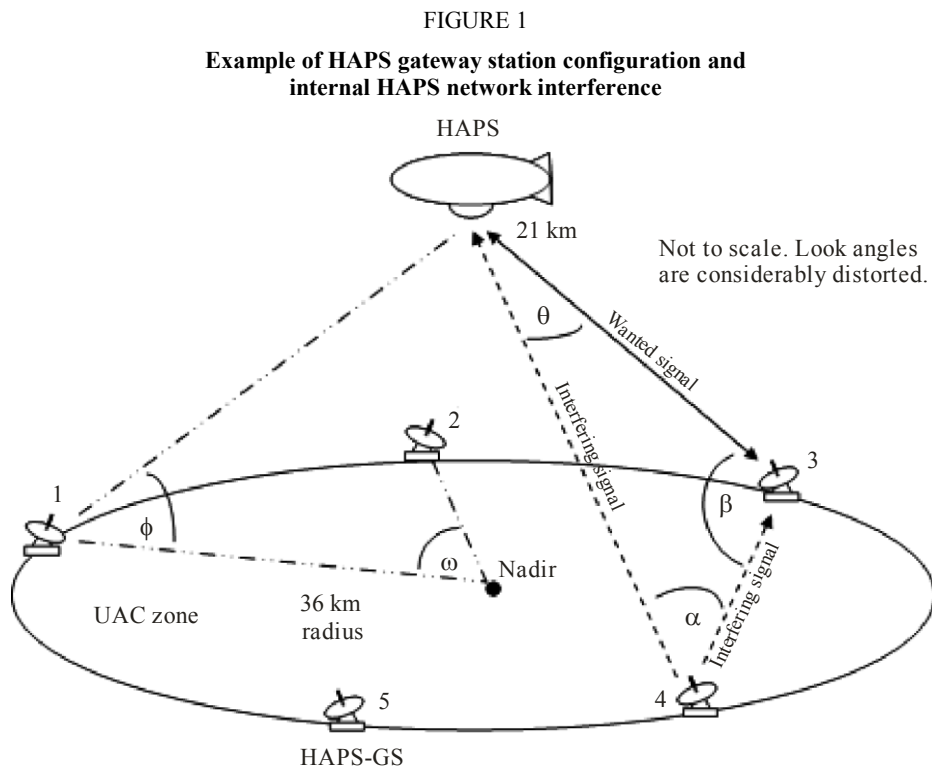


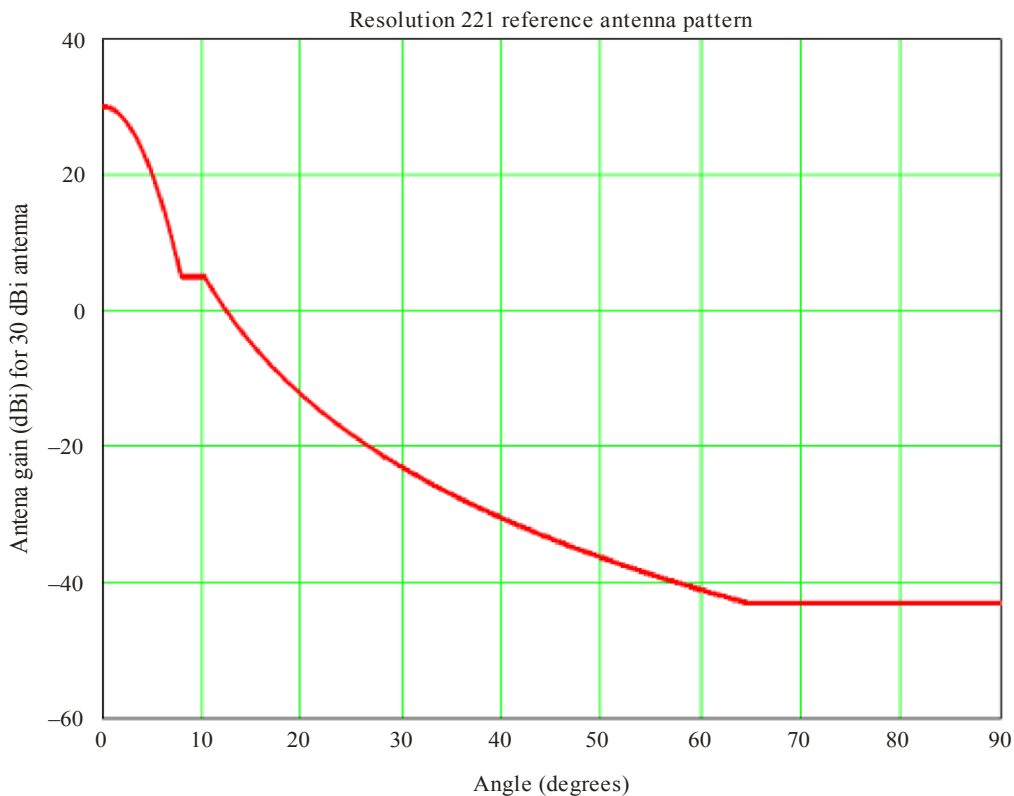
TABLE 1
Characterization of the HAPS platform transmitter

Parameter	Symbol	Value
Frequency (GHz)		6.5
Transmit power (dBW)		-22
Bandwidth (MHz)		11
Transmit power density (dBW/MHz)	P_t	-32.4
Transmit feeder loss (dB)		4.1
Maximum antenna gain (dBi)	G_{max}	30
Main beam 3 dB beamwidth (degrees)		5.2
Reference antenna pattern β_h degrees from maximum (dBi)	$G_h(\beta_h)$	Resolution 221 (Rev.WRC-07)
Height of HAPS platform (km)	A_h	21.0

The following HAPS antenna is considered in these analyses:

Resolution 221 (Rev.WRC-07) array antenna: This is the antenna pattern that appears in Resolution 221 (Rev.WRC-07). It has a near side-lobe level of 25 dB below the main-beam gain of 30 dBi. The gain for angles more than 63° from the main-beam axis is -43 dBi as shown in Fig. 2. No working model of an antenna conforming to this pattern has been manufactured or demonstrated.

FIGURE 2
Gain pattern for Resolution 221, antenna having a maximum gain of 30 dBi



The characteristics assumed for the FS receiver are summarized in Table 2. These values are consistent with values in Recommendation ITU-R F.758.

TABLE 2
FS parameters

Parameter	Symbol	Value
Frequency (GHz)	f_{GHz}	6.5
Maximum antenna gain (dBi)	G_{rmax}	45.0
Reference antenna pattern gain β_r degrees from maximum (dBi)	$G_r(\beta_r)$	Recommendation ITU-R F.699
Antenna height (km)	A_f	0.060
Antenna elevation angle (degrees)	α	0.0
Feeder loss (dB)	L_f	3.0
Receiver noise temperature (Kelvins)	T_{eff}	725
Reference bandwidth (MHz)	B	1.0
Receiver noise floor (dBW/MHz)	N_T	-140.0

The interfering signal power at a fixed service receiver is determined by the following equation:

$$I_r = P_t + G_h(\beta_h) + G_r(\beta_r) - L_b - L_f \quad (1)$$

where all terms have been defined in Tables 1 and 2 except for L_b , the propagation loss. The propagation loss is determined as:

$$L_b = 92.4 + 20 \log(f_{GHz}) + 20 \log(d_{km}) \quad (2)$$

where d_{km} is the length of the propagation path in kilometres from the HAPS platform transmitter to the FS receiving antenna.

The interference power is assumed to propagate on a straight line path within the plane of the great circle determined from the positions of the HAPS transmitter, the FS receiver, and the centre of the Earth where the Earth is assumed to have a radius (8 504 km) that is 4/3 of its actual value (6 378 km). This allows the effect of atmospheric refraction to be taken into account. The I/N ratio used in this study is the difference between the value of the interference power I_r of equation (1) and the noise power N_T given in Table 2 with both values given in dBW/MHz.

3 Interference criteria

Before discussing the simulation methodologies it is necessary to determine the appropriate interference criteria to be applied in this sharing situation. The interference criteria used by the fixed service is considered to be a matter for each administration to decide. In the Radio Regulations HAPS is considered to be an application within the fixed service; however, it is not clear how administrations would choose to treat it. For the purpose of discussion, a HAPS transmitting station will be treated here as any other FS transmitting station.

At the present time there is no agreed value for acceptable interference from HAPS. On the assumption that the HAPS system is entering into an environment heavily used by the FS and already shared with the FSS, any new HAPS system, if permitted under RR No. 4.15A, should be allowed to add to the interference noise only incrementally. Assuming a 20% allowance for the total contribution of interference from all sources to the total noise, a value of 10% of this allowance could be allocated to HAPS interference. This would result in an I/N criterion of about -17 dB for HAPS systems.

Administrations may choose other allowances and allocations, but a range of I/N values between -10 and -20 dB would appear to be of the greatest interest. This is the range that will receive the greatest attention in the following developments. To cover all eventualities results have been calculated for all I/N ratios between 0 and -20 dB.

4 Description and application of the I/N methodology

The I/N at an FS receiver, using the parameters specified in Tables 1 and 2, would depend on its position in the layout of Fig. 1 and on the azimuth of the main beam axis of its antenna. This section considers the case where the HAPS platform transmits to only a single gateway station on the surface of the Earth. All geographic locations are specified by their great circle distance from the point on the surface of the Earth that is directly below the HAPS platform. In HAPS terminology, the point on the surface of the Earth directly below the HAPS platform is often described as the HAPS nadir. In this Annex, it will be designated as the HAPS Sub-Platform Point (SPP). The other coordinate needed to specify a geographic location is the azimuth angle of the great circle path from the SPP to the point. This angle is measured at the HAPS SPP in a counter-clockwise direction from the azimuth to the gateway station.

The method described in this section is to determine the locations where a given I/N level will be exceeded for the two extreme pointing azimuths of the FS antenna at each location. One case is where the azimuth of the FS receiving antenna is directed along the great circle toward the HAPS SPP. The other is where the azimuth of the FS receiving antenna is directed 180° from the direction toward the HAPS SPP. The areas where a given I/N ratio will be exceeded for the case where the FS antenna is pointed toward SPP will be called a coordination area since a frequency coordination process would be needed to determine whether that I/N would be exceeded for a particular receiver. The geographical region, if any, where the I/N ratio would be exceeded for the case where the FS antenna is pointed away from SPP will be called an exclusion zone because there is no pointing angle for which the I/N ratio would not be exceeded. As used in this Annex, an exclusion zone is specific to the model parameters and to the I/N value chosen for an interference criterion.

The radial extent of a coordination or exclusion zone is determined by stepping along a great circle path from the HAPS SPP and determining at each step whether an edge of a particular I/N geographical region has been encountered. The calculation numbers successive areas on each azimuth where a threshold I/N ratio is exceeded. All of the elemental areas with the same number are considered to be part of the same composite geographical region.

Figure 3 shows the results of such a calculation for an I/N threshold of -20 dB using the HAPS array antenna transmitting to a gateway station that is 36 km from the SPP and using the parameters from Tables 1 and 2. (The characteristic values of Tables 1 and 2 are used for all subsequent calculations unless otherwise noted.) The I/N threshold of -20 dB was chosen for Fig. 3 and the following figures to illustrate cases where exclusion zones exist. For this case, the coordination area is identified with the dotted line and the exclusion zone with the solid line. These areas surround the location of the gateway station and, therefore, must result from the coupling of the main-beam gain of the HAPS array to the side lobes of the FS antenna. Because the gain pattern of the HAPS array

antenna rolls off so rapidly with the angle from main-beam axis, there is no area due to the HAPS side lobes coupling energy to the main lobe of an FS receiving antenna for this case.

Rather than provide plots for other I/N ratios, Table 3 summarizes the results for various I/N thresholds by tabulating the areas of the coordination area and exclusion zone for each I/N . For this example all of the entries in the Area 2 column are zero, which means that there is only one coordination area. The entries in the column for the area of Area 2 are zero and the entries for the total coordination area are the same as those for Area 1.

Note that in cases where Area 2 is zero, Area 1 is a contiguous geographical region. Where Area 2 is not zero, the various components of Area 1 may not be contiguous. This result is discussed further in Section 6 of this Annex.

When there is a geographical region near a gateway where the HAPS antenna main beam couples sufficient energy into the FS antenna side lobes to exceed the I/N threshold, there may be an exclusion zone. An exclusion zone will always be surrounded by a coordination area. For each I/N value there can be no more than one exclusion zone per gateway station. Thus, for all cases considered in this section there is only one exclusion zone.

From Table 3, the coordination area and exclusion zone decrease gradually with increasing I/N . The exclusion zone disappears for an I/N threshold of -19 dB or greater and the coordination area disappears for an I/N value of -14 dB or more.

FIGURE 3

Coordination and exclusion regions with array antenna
Gateway is 36 km from HAPS sub-platform point, $I/N = -20$ dB

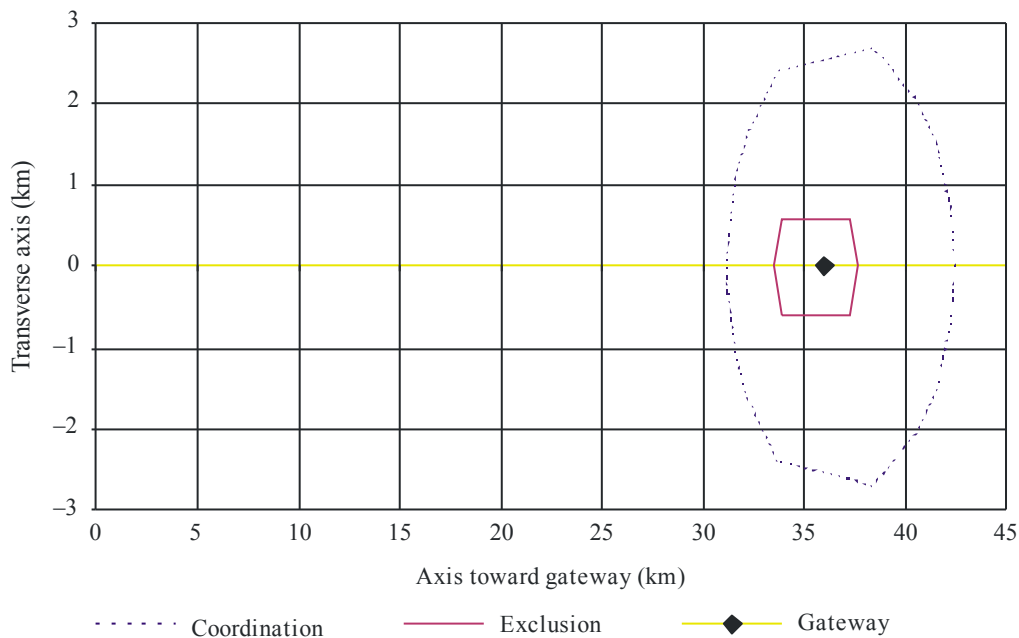


TABLE 3

**Areas of coordination and exclusion zones with array antenna
when gateway is 36 km from the SPP**

<i>I/N</i>	Area 1 (km ²)	Area 2 (km ²)	Total area of coordination (km ²)	Exclusion zone (km ²)
-20	50.4	0	50.4	6.6
-19	40.2	0	40.2	0
-18	32.9	0	32.9	0
-17	24.3	0	24.3	0
-16	16	0	16	0
-15	6.9	0	6.9	0
-14	0	0	0	0

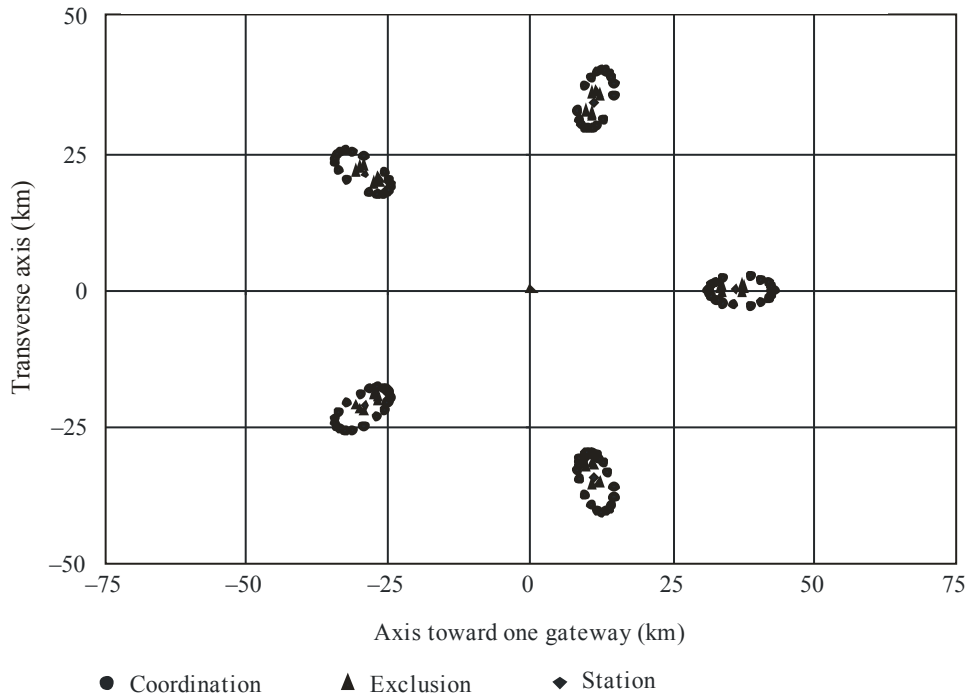
5 Aggregate interference from HAPS platforms to FS point-to-point receivers

This section considers the effect of HAPS platform transmitters operating to multiple gateway stations. Figure 4 shows the coordination areas and exclusion zones for an *I/N* of -20 dB in the case where there are five gateway stations equally spaced at a distance of 36 km from the HAPS nadir. Table 4 shows the areas of the coordination and exclusion zones for this case. It is clear that because of the low gain of this antenna in the far side-lobe sectors there are no new areas caused by the aggregation of the power transmitted to the five gateway ground stations. This is clearly the case for an *I/N* of -20 dB and, therefore, will be the case for all more positive *I/N* values. This result is due to the rapid fall-off of antenna gain with increasing off-axis angle that is the characteristic of the Resolution 221 (Rev.WRC-07) array antenna.

Each of the individual coordination areas and exclusion zones in Fig. 4 is virtually identical to the same areas in Fig. 3. These areas in Table 4 are just five times the values given in Table 3.

FIGURE 4

Coordination and exclusion regions for array antennas
with five gateway stations, $I/N = -20$ dB



F.5-1006-04

TABLE 4

Areas of coordination and exclusion zones for array antennas
with five gateways 36 km from the SPP

I/N	Area 1 (km^2)	Area 2 (km^2)	Total area of coordination (km^2)	Exclusion zone (km^2)
-20	251.8	0	251.8	33.2
-19	201.1	0	201.1	0
-18	163.8	0	163.8	0
-17	120.8	0	120.8	0
-16	80.1	0	80.1	0
-15	34.7	0	34.7	0
-14	0	0	0	0

6 Consideration of FS elevation angle and gateway distance from SPP

In all of the previous examples, the elevation angle of the FS antenna has been considered to be 0 degrees. Elevation angles of up to 5 degrees have no effect on the areas of the coordination areas and exclusion zones for the Resolution 221 array antenna. They remain as shown in Figs. 3 and 4 and in Tables 3 and 4. The cases where the use of this antenna could produce additional areas where

the interference into a FS receiver would exceed a threshold value are those involving either large FS elevation angles, or increased distances for the gateway station in addition to non-zero FS elevation angles. Figure 5 shows the coordination areas and exclusion zones that would be obtained for an elevation angle of 3 degrees if a single gateway were 76 km from the HAPS SPP. Such an operation would require an increase in transmit power in order to maintain the link margin.

To facilitate discussions it is useful to designate the areas where I/N exceeds a threshold value because of coupling between the main lobe (ML) of the HAPS antenna and the side lobes (SL) of the FS antenna as ML-SL areas and the areas where I/N exceeds a threshold value because of coupling between the side lobes of the HAPS antenna and the main lobe of the FS antenna as SL-ML areas. The ML-SL geographical region is only identifiable as Area 1 at azimuth angles about the SPP where Area 2 is not present (has no area).

There are several important characteristics of SL-ML areas. One is that they tend to be very large when they do exist as may be seen from the total areas for coordination areas in Table 5. Another is that SL-ML areas occur at distances from the HAPS SPP that are beyond the distance to the gateway, possibly out to the limits of line-of-sight visibility. At azimuths from the HAPS SPP that pass close to the gateway there will be I/N ratios for which both Area 1 and Area 2 are encountered. Thus, only the portion of the larger geographical region in Fig. 5 that is blocked by the ML-SL geographical region will appear in Area 2. The remainder of the area of the larger geographical region will be aggregated with the area of the ML-SL geographical region in Area 1.

The input parameters used in generating Fig. 5 and Table 5 do not produce an extremely large SL-ML coordination area. However, the coordination area that they produce does not disappear until the I/N threshold is -2 dB or greater.

FIGURE 5
**Coordination and exclusion regions for array antennas with gateway 76 km
 from nadir, $P_t = -26.4$ dBW/MHz, $G_{tmax} = 30$ dBi,
 FS antenna elevation angle = 3 degrees, $I/N = -20$ dB**

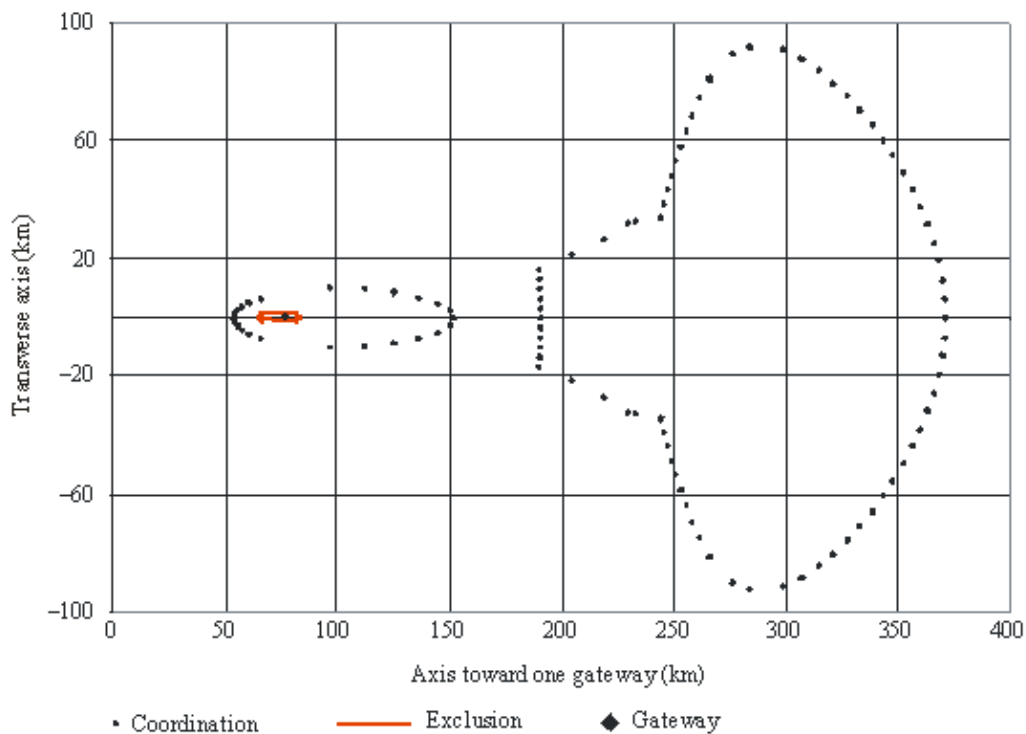


TABLE 5

Areas of coordination and exclusion zones for an array antenna with a single gateway station 76 km from the SPP, $P_t = -24.4$ dBW/MHz, $G_{max} = 34$ dBi, and FS antenna elevation angle of 3 degrees

I/N	Area 1 (km ²)	Area 2 (km ²)	Total area of coordination (km ²)	Exclusion zone (km ²)
-20	9 931.6	12 256	22 187.7	63.1
-19	8 593.9	11 572.6	20 166.6	23.6
-18	8 539.7	8 527.3	18 226.3	0
-17	8 544.9	6 685.9	16 387.3	0
-16	7 475.1	6 038.6	14 661.8	0
-15	6 454.2	2 532.3	13 027.4	0
-14	5 475.5	5 879.1	11 354.6	0
-13	5 445.1	4 640.2	10 085.3	0
-12	4 614.8	4 376.5	8 991.3	0
-11	3 804	4 100.1	7 904.1	0
-10	3 007	3 809.5	6 816.5	0
-9	2 963.3	2 791.6	5 754.8	0
-8	2 203.8	2 535	4 738.8	0
-7	2 074.4	1 655.8	3 730.2	0
-6	1 367.8	1 437.1	2 804.9	0
-5	1 169.2	733.4	1 902.6	0
-4	881.3	187.9	1 069.2	0
-3	255.7	0	255.7	0
-2	0	0	0	0